CAL Project No. HM-2107-Y

CORNELL AERONAUTICAL LABORATORY, INC.
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Quarterly Progress Report No. 2

ROCKET BASE FLOW FIELD STUDIES USING AN ELECTRON BEAM PROBE

Contract No. NSR 33-009-030
Project No. PR 10-6188

Reporting Period: 26 September 1965 through 25 December 1965

Summary

During the reporting period two of the primary pretest objectives were realized: (1) the rotational temperature measuring apparatus was statically calibrated (photomultiplier output ratio vs nitrogen test gas temperature), and (2) the design of required model equipment was completed.

System Calibration

Having completed the first tasks involving assembly and alignment of the optical apparatus and checkout of the electron beam generating equipment, a static calibration of the system was undertaken. This experiment involved the calibration of the ratio of the outputs of the two photomultiplier channels of the apparatus as a function of test gas temperature.

To accomplish this calibration, an oven was fabricated in which nitrogen gas could be maintained at known levels of temperature and pressure. This oven, shown in Fig. 1, attaches to the electron beam equipment; the beam-generated fluorescence within the oven is observed through a glass window in the oven wall. Oven temperature is determined using thermocouples embedded in the oven wall. Equilibrium between oven wall and test gas temperatures is assured by maintaining a low flow rate of nitrogen through the oven and by preheating the gas before admission to the oven test chamber; the flow rate, however, is sufficient to eliminate the possibility of erroneous data resulting from localized heating of the gas by the beam.

Initial measurements of the output signals were found to have poor repeatability; that is, values of R, the ratio of the two photomultiplier output signals measured at a given temperature, varied as much as ±10%. Since calibration curves presented by Muntz[1] using nearly identical equipment indicated a percentage error in temperature of three to five times the percentage error in R, the ±10% uncertainty in R was considered excessive. The source of this difficulty was the poor signal-to-noise ratio of the output signals as the result of the very low light levels incident on the photomultiplier cathodes. To remedy this situation, a change was made in the electron beam apparatus to improve the transmission of the electron beam through three orifices (required for dynamic pumping stages) between the electron gun and calibration oven. The increase in transmitted beam current increased the intensity of the fluorescence. In addition, the optical system inlet aperture was enlarged from a .040 in. diameter hole to a .060 in. by .120 in. slot to admit more light to the photomultipliers. These changes improved the signal-to-noise ratio so that R could be measured repeatedly within ±3% for a given set of test conditions, which is considered acceptable.

With an operative system in hand, the actual static calibration experiments were initiated. The calibration procedure was as follows. The oven heaters were adjusted to bring the temperature to a desired level; at the same time, the calibration lamp temperature was carefully adjusted so that the light flux level incident on the photomultipliers (from the lamp) would be close to that experienced during observation of the beam-excited fluorescence. The nitrogen supply was adjusted to maintain a desired oven pressure. With the oven temperature and pressure stabilized, the beam was turned on and the outputs of the two channels of the apparatus recorded; the beam was then extinguished, the calibration lamp shutter opened, and the apparatus outputs recorded. The measurement was then repeated before the oven temperature was changed.

Prior to determining the dependence of R on temperature, data were taken to verify the independence of R (hence, the temperature measurement) on beam accelerating voltage, beam current, and test gas density. These data are presented in Fig. 2. In each case the range of variation of the parameter being examined was limited to that for which the remaining variables could be held constant. All data were obtained at room temperature; the other operating conditions are as noted. The results indicate that, for the ranges examined, the temperature measurement is independent of test gas density, beam accelerating voltage, and beam current.

The experimental determination of R as a function of temperature was first attempted starting at room temperature with the temperature incrementally increased until control over the oven pressure was lost due to failure of the high temperature seals on the oven windows at about 550°K. During the calibration oven pressure was maintained at about 300 microns Hg A, well within the range investigated for Fig. 2.

Examination of the results revealed an apparent insensitivity of R to temperature above about 450°K. It was suspected that mercury vapor might be present in the oven (due to backstreaming from a McLeod gauge used to measure oven pressure) causing the loss of sensitivity. Since insensitivity of R to test gas density had been demonstrated, the McLeod gauge was replaced with a thermocouple gage. A more likely cause, however, was contamination of the oven atmosphere by fluorine gas liberated at high temperatures from the fluoro-elastomer O-ring seals; presence of fluorine was evidenced by etching of the glass window in the oven wall. Since the emission spectrum of fluorine is relatively strong in the region of the nitrogen band being observed, it was felt that the presence of fluorine could cause the apparent loss of sensitivity of R to temperature at high temperatures. To eliminate this possibility, the rubber O-rings were replaced with pure aluminum sealing rings.

A final calibration was performed starting again at room temperature and terminating this time at 573°K, the approximate upper operating limit of the oven. The results are shown in Fig. 3. Examination of the data indicates that, near room temperature, an uncertainty in R of ±3% results in an uncertainty in temperature of about ±10%; moreover, the higher the temperature, the smaller the percentage error in temperature for the same uncertainty in R. This curve (Fig. 3) is the calibration curve that will be used in future temperature measurements.

Model Design

There are three basic design tasks for this program. These are:

(1) rework of the existing Saturn S-IV 4-engine model heat shield to provide a viewing window for the rotational temperature apparatus (RTA) objective lens.

(2) design of nozzle adapters of extended length to provide adequate space for the R. T. A. to be positioned behind the heat shield.

(3) design of a support bracket for the R. T. A.

The modified heat shield is shown in Fig. 4. Provisions for heat transfer and pressure measuring instrumentation have been made along two radii between engines. Along the other two radii are: (1) the fibre optic units previously employed on the electron beam density program so that density measurement may be taken along with the temperature measurements (beam spreading should not be prohibitive) and (2) a glass-covered slot through which the R. T. A. objective lens will focus on the beam.

Provision for insertion of the R. T. A. behind the heat shield has been made by designing extended nozzle adapters. These adapters allow space for the required axial movement of the R. T. A. relative to the beam to maintain focussing (the fixed objective lens has a 2-inch focal length).

The basic design requirements for the R. T. A. support bracket are:

(1) to provide radial mobility in order to position the objective lens at positions corresponding to the fibre optic locations so that spatial correlation of the temperature and density data may be made.

(2) to suspend the R. T. A. from the electron beam gun support pedestal in order to isolate the unit from shocks during model firing and to maintain the beam/lens orientation.

Figure 5 shows a schematic of the overall installation of the test equipment in the high altitude chamber. Ideally, with this support scheme for the R. T. A., once the lens has been focussed on the beam (at a given radial location with respect to the heat shield), simply moving the gun support pedestal on the guide rails will allow an axial temperature survey (i. e., distance above the heat shield) to be made, as the beam/lens orientation remains fixed. Vernier dimensional adjustment capability has been incorporated in the R. T. A. support bracket design and allows for corrections to be made for slight dimensional and/or optical misalignments.

Scheduling now calls for the release of drawings for parts fabrication to occur in about mid-January. With the present six to eight weeks fabrication time estimate, parts delivery to CAL remains consistent with the current testing schedule.

Status

Based on the current testing schedule of the CAL/NASA high-altitude facilities, the test program should begin in early March, a date consistent with estimated parts fabrication time. This test schedule, however, is not consistent with the present contract performance period in that it does not realistically allow adequate time for completion of the test program, data analysis and the preparation of a final report. Consequently, a three-month/ no additional cost extension of the performance period has been requested.

Program expenditures as of the end of the reporting period amount to approximately 60% of the program allowance, [redacted]

[redacted]

REFERENCES

1. Muntz, E. P. and Abel, S. J.: "The Direct Measurement of Static Temperatures in Shock Tunnel Flows," General Electric Co. Report No. R64SD25, 1964.

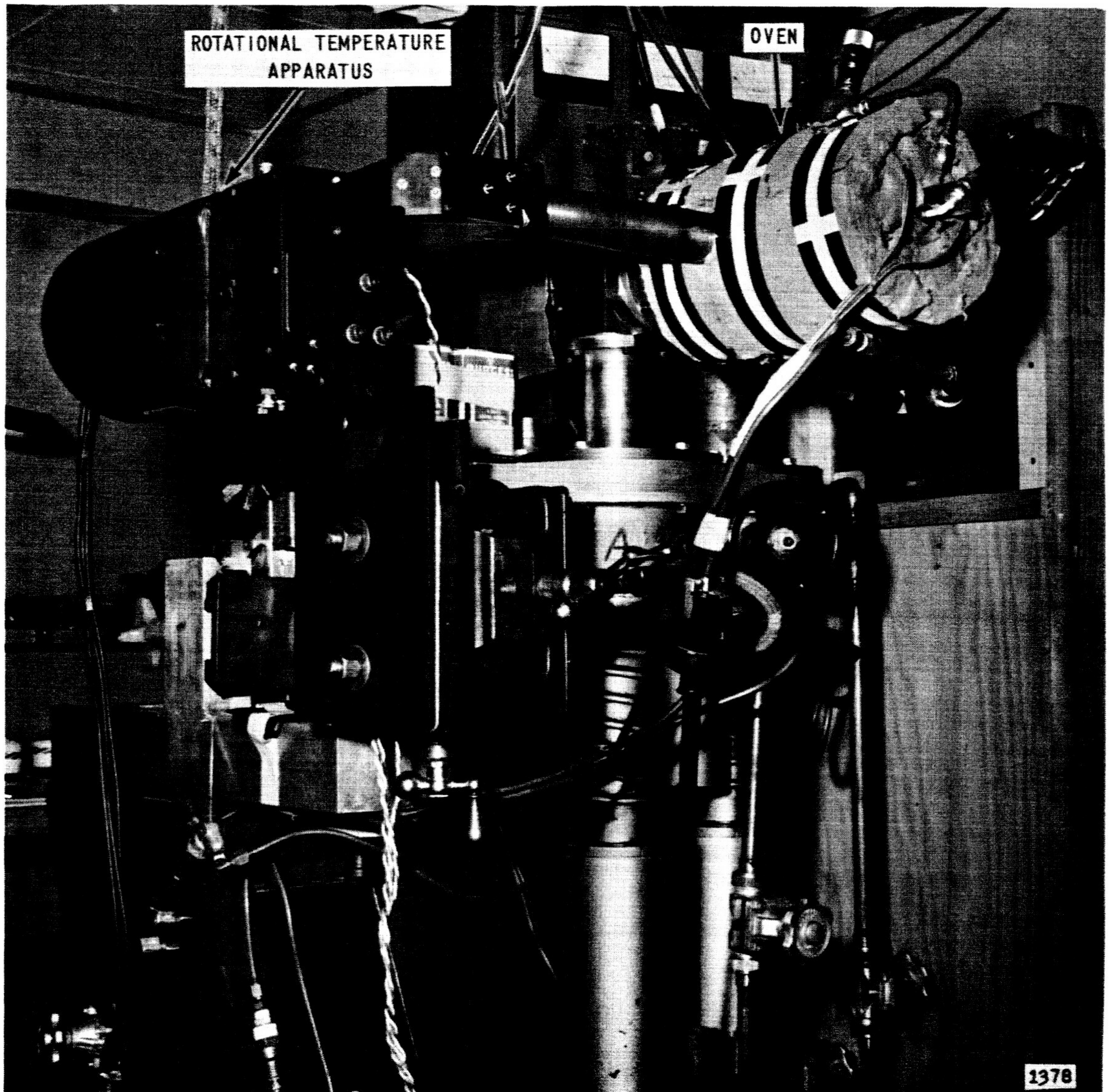

Figure I CALIBRATING OVEN AND ROTATIONAL TEMPERATURE APPARATUS

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VISIGRAPH MADE IN U.S.A.

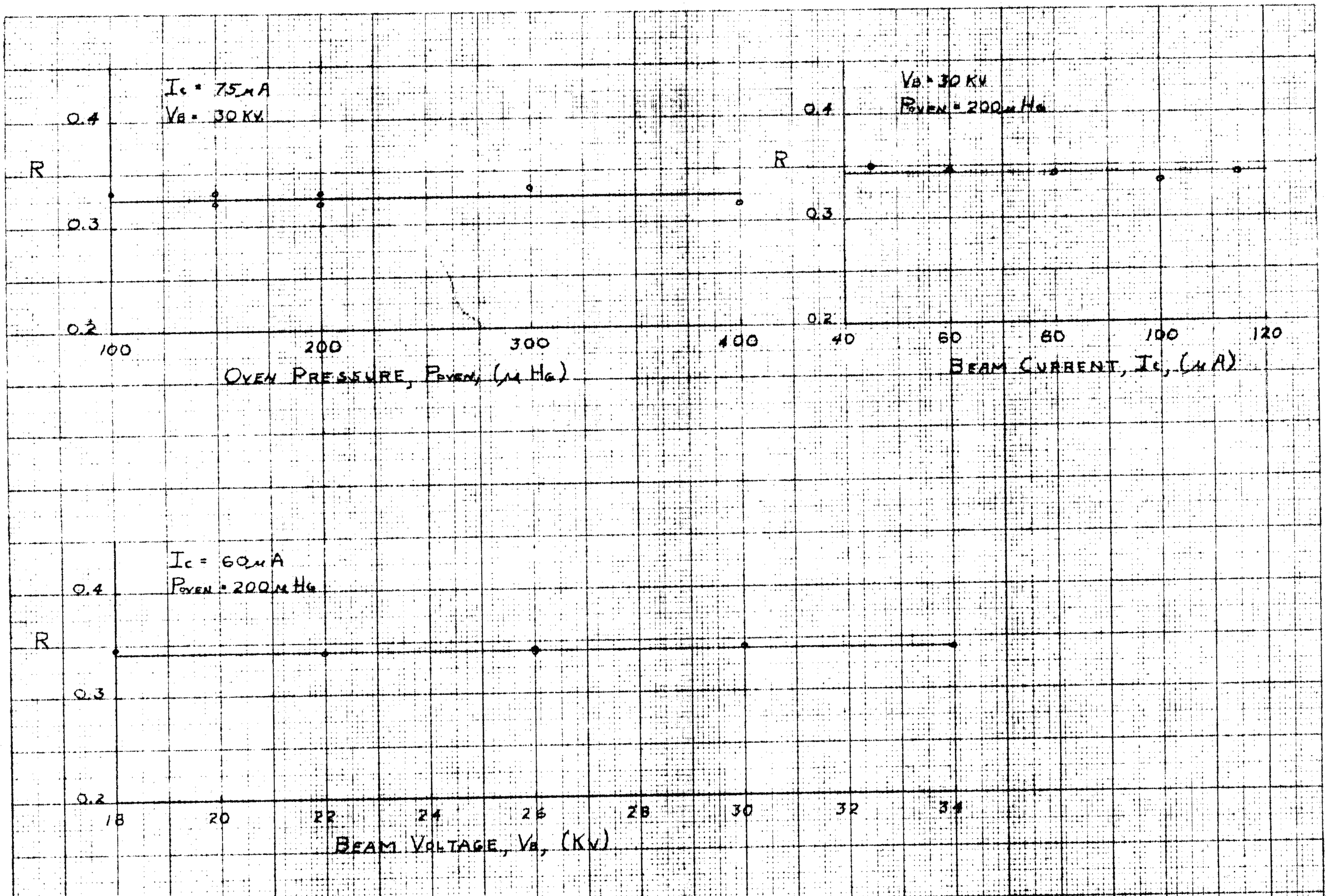


FIGURE 2

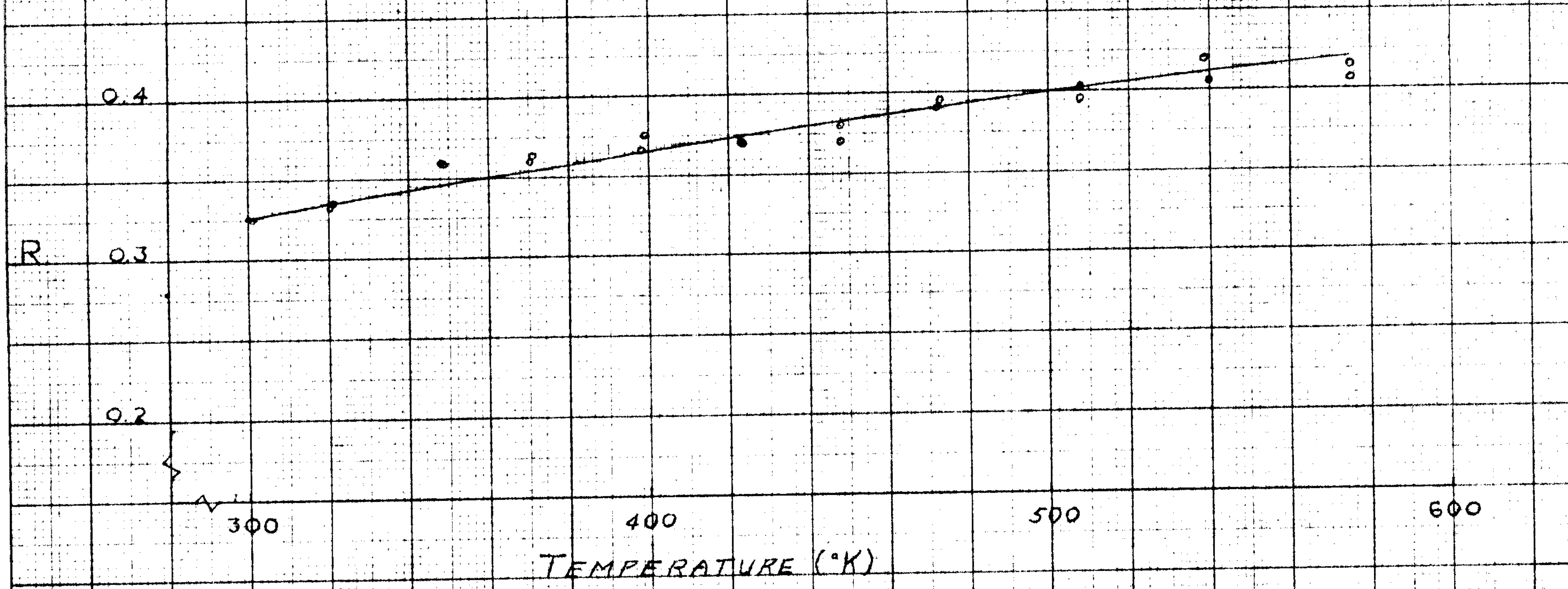


FIGURE 3. CALIBRATION CURVE FOR TEMPERATURE MEASURING APPARATUS

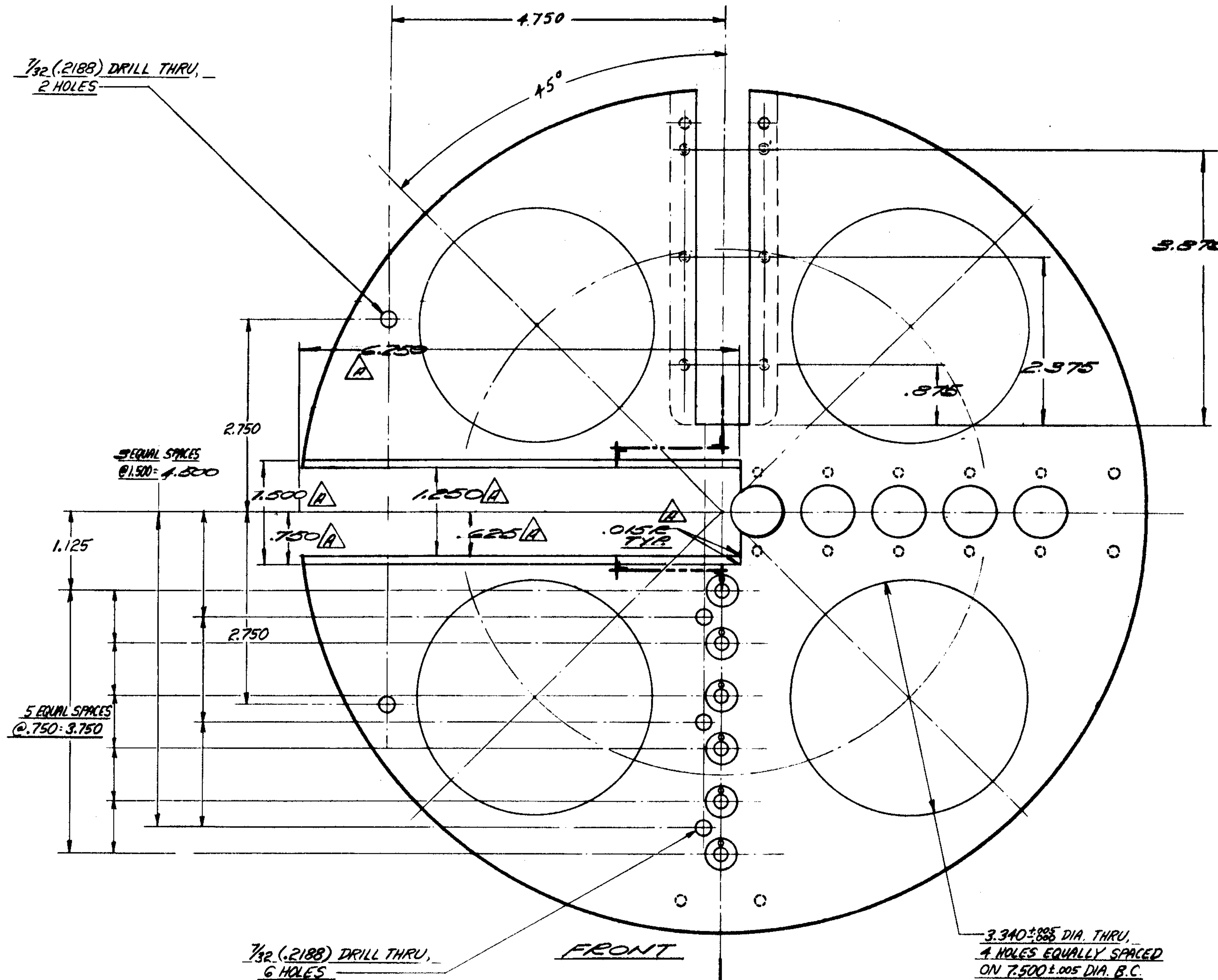
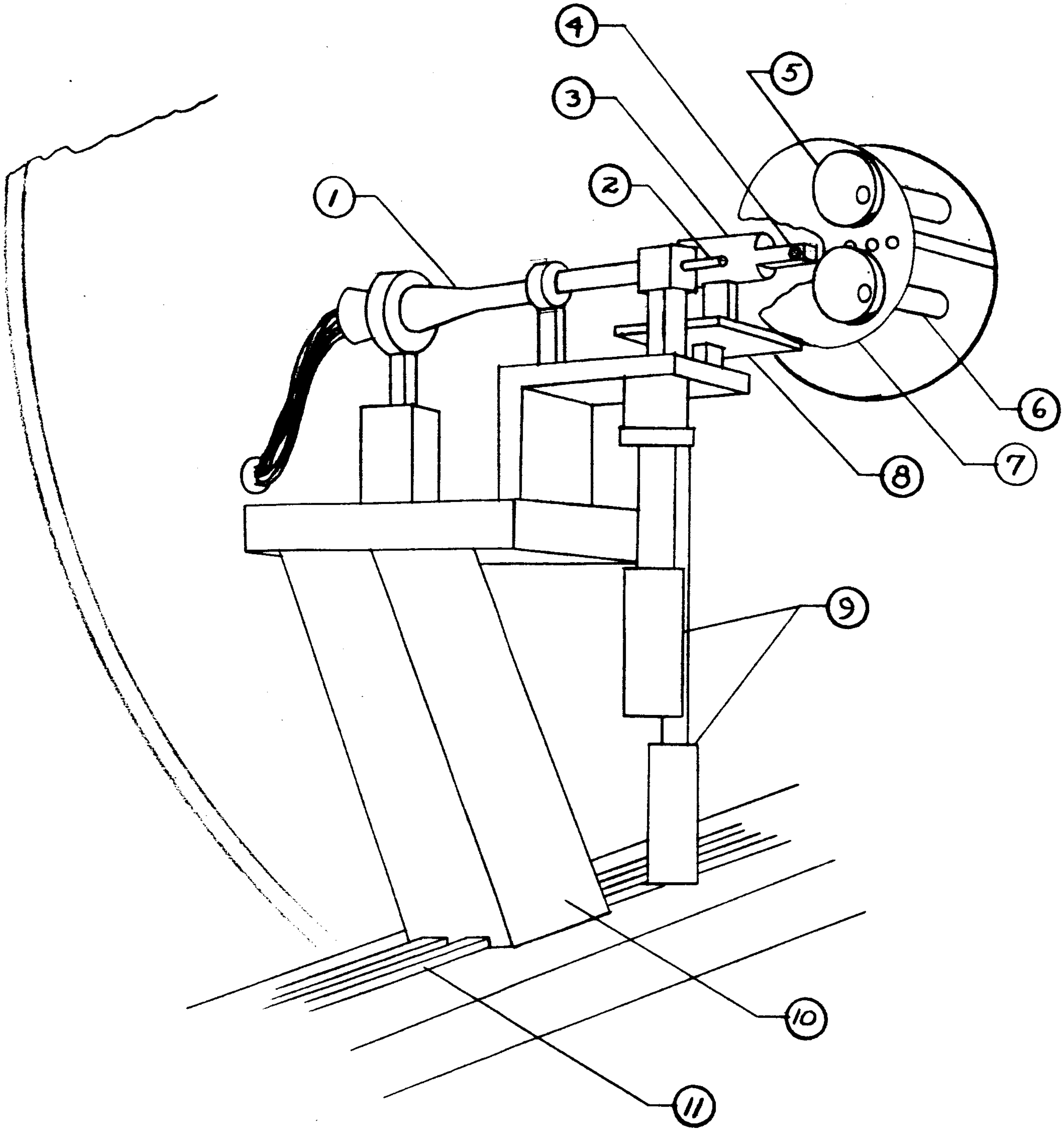


Figure 4 ELECTRON BEAM TEMPERATURE STUDY - MODIFIED HEAT SHIELD



1.	Electron Gun	7.	Heat Shield
2.	Drift Tube	8.	Support Bracket
3.	R. T. A.	9.	Diffusion Pumps
4.	Objective Lens	10.	Support Pedestal
5.	Nozzle	11.	Guide Rails
6.	Adapter		

Figure 5 ELECTRON BEAM TEMPERATURE STUDY-
INSTALLATION SCHEMATIC